PCT W INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G01V 1/28

A1

(11) International Publication Number: WO 96/18915

(43) International Publication Date: 20 June 1996 (20.06.96)

(21) International Applicati n Number: PCT/US95/13644

(22) International Filing Date: 5 October 1995 (05.10.95)

(30) Pri rity Data:
08/353,934 12 December 1994 (12.12.94) US

(71) Applicant: AMOCO CORPORATION [US/US]; Law Dept., Mail Code 1907A, 200 E. Randolph Drive, P.O. Box 87703, Chicago, IL 60680-0703 (US).

(72) Inventors: BAHORICH, Michael, S.; 10585 W. 69th Place, Arvada, CO 80004 (US). FARMER, Steven, L.; 903 S. NewHaven Avenue, Tulsa, OK 74112 (US).

(74) Agent: GABALA, James, A.; Amoco Corporation, Law Dept., Mail Code 1907A, 200 E. Randolph Drive, P.O. Box 87703, Chicago, IL 60680-0703 (US).

(81) Designated States: AU, CA, CN, GB, MX, NO, RU, TT, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published

With international search report.
With amended claims and statement.

(54) Title: METHOD OF SEISMIC SIGNAL PROCESSING AND EXPLORATION

(57) Abstract

A method for the exploration of hydrocarbons, comprising the steps of: obtaining a set of seismic signal traces distributed over a pre-determined three-dimensional volume of the earth; dividing the three-dimensional volume into a plurality of vertically stacked and generally spaced apart horizontal slices; dividing each of the slices into a plurality of cells having portions of at least three seismic traces located therein; measuring the cross-correlation between one pair of traces lying in one vertical plane to obtain an in-line value and the cross-correlation between another pair of traces lying in another vertical plane to obtain a cross-line value; combining the in-line value and the cross-line value to obtain one coherency value for each of the cells; and displaying the coherency values.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	GB	United Kingdom	MR	Mauritania
AU	Australia	GE	Georgia	MW	Malawi
BB	Barbados	GN	Guinea	NE	Niger
BE	Belgium	GR	Greece	NL	Netherlands
BF	Burkina Faso	HU	Hungary	NO	Norway
BG	Bulgaria	IE	Ireland	NZ	New Zealand
BJ	Benin	IT	Italy	PL	Poland
BR	Brazil	JP	Japan	PT	Portugal
BY	Belarus	KE	Kenya	RO	Romania
CA	Canada	KG	Kyrgystan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo			SE	Sweden
CH	Switzerland	KR	Republic of Korea	SI	Slovenia
CI	Côte d'Ivoire	KZ	Kazakhstan	SK	Slovakia
CM	Cameroon	LI	Liechtenstein	SN	Senegal
CN	China	LK	Sri Lanka	TD	Chad
CS	Czechoslovakia	LU	Luxembourg	TG	Togo
CZ	Czech Republic	LV	Latvia	TJ	Tajikistan
DE	Germany	MC	Monaco	TT	Trinidad and Tobago
DK	Denmark	MD	Republic of Moldova	UA	Ukraine
ES	Spain	MG	Madagascar	US	United States of America
FI	Finland	ML	Mali	UZ	Uzbekistan
FR	France	MN	Mongolia	VN	Viet Nam
GA	Gabon				

METHOD OF SEISMIC SIGNAL PROCESSING AND EXPLORATION

Technical Field

This invention relates to the general subject of seismic exploration and, in particular, to methods for identifying structural and stratigraphic features in three dimensions.

Background Of The Invention

Ordinary 2-D seismic data is acquired along lines (See lines 10 and 11 in FIG. 1) that consist of geophone arrays onshore or hydrophone streamer traverses offshore. Geophones and hydrophones act as sensors to receive energy that is transmitted into the ground and reflected back to the surface from subsurface rock interfaces 12. Energy is usually provided onshore by vibroseis vehicles which transmit pulses by shaking the ground at pre-determined intervals and frequencies on the surface. Offshore, airgun sources are usually used. Subtle changes in the energy returned to surface often reflect variations in the stratigraphic, structural and fluid contents of the reservoirs.

In 3-D seismic the principle is similar, however, lines and arrays are more closely spaced (See FIG's. 1 and 2) to provide more detailed subsurface coverage. With this high density coverage, extremely large volumes of digital data need to be recorded, stored and processed before final interpretation can be made. Processing requires extensive computer resources and complex software to enhance the signal received from the subsurface and to mute accompanying noise which masks the signal.

Once the data is processed, geophysical staff compile and interpret the 3-D seismic information in the form of a 3-D cube (See FIG. 4) which effectively represents a display of subsurface features. Using the data cube, information can be displayed in various forms. Horizontal time slice maps can be made at selected depths (See FIG. 5). Using a computer workstation an interpreter can slice through the field to investigate reservoir issues at different horizons. Vertical slices or sections can also be made in any direction using seismic or well data. Time maps can be converted to depth to provide a structural interpretation at a specific level.

Three-dimensional (3-D) seismic is being used extensively worldwide to provide a more detailed structural and stratigraphic image of subsurface reservoirs. Acceptance of 3-D seismic has accelerated during the last five

years based on a proven track record that continues to grow. The 3-D payout has been measured by increased reserve estimates, cost savings from more accurate positioning of delineation and development wells, improved reservoir characterization leading to better simulation models, and the ability to predict more accurately future opportunities and problems during the production history of a field. More importantly, 3-D seismic has also been used as an exploration tool to reduce drilling risk in structurally complex areas and to predict reservoir quality in undrilled areas.

As good as 3-D seismic surveys and interpreters have become, improvements are needed.

In particular, seismic data has been traditionally acquired and processed for the purpose of imaging seismic reflections. Changes in stratigraphy are often difficult to detect on traditional seismic displays due to the limited amount of information that stratigraphic features present in a cross-section view. Although such views provide an opportunity to see a much larger portion of these features, it is difficult to identify fault surfaces within a 3-D volume where no fault reflections have been recorded. More importantly, seismic data is not known to have been acquired or used for the purpose of imaging seismic discontinuities instead of seismic reflections.

Summary Of The Invention

In accordance with the present invention, a method is disclosed for the exploration of hydrocarbons. The method comprises the steps of: obtaining a set of seismic signal traces distributed over a pre-determined three-dimensional volume of the earth; dividing the three-dimensional volume into a plurality of vertically stacked and generally spaced apart horizontal slices; dividing each of the slices into a plurality of cells that are arranged into laterally extending rows and columns and that have portions of at least three generally vertically extending seismic traces located therein; measuring across each of the cells the cross-correlation between one pair of traces lying in one vertical plane to obtain an in-line value and measuring the cross-correlation between another pair of traces lying in another vertical plane to obtain a cross-line value that are estimates of the time dip in an in-line direction and in a cross-line direction; combining the in-line value and the cross-line value to obtain one coherency value for each of the cells; and displaying the coherency values of the cells across at least one horizontal slice.

This technique is particularly well suited for interpreting fault planes within a 3-D seismic volume and for detecting subtle stratigraphic features in 3-D. This is because seismic traces cut by a fault line generally have a different seismic character than traces on either side of the fault. Measuring trace similarity, (i.e., coherence or 3-D continuity) along a time slice reveals lineaments of low coherence along these fault lines. Such coherency values can reveal critical subsurface details that are not readily apparent on traditional seismic sections. Also by calculating coherence along a series of time slices, these fault lineaments identify fault planes or surfaces.

Numerous other advantages and features of the present invention will become readily apparent from the following detailed description of the invention, the embodiments described therein, from the claims, and from the accompanying drawings.

Brief Description of the Drawings

FIG. 1 illustrates an arrangement of geophones to obtain 3-D seismic data from the earth's subsurface for processing in accordance with the present invention;

FIG. 2 is a plan view of the arrangement shown in FIG. 1;

FIG. 3 is a representation of the seismic traces laying in a plane passing through one row of geophones shown in FIG. 2;

FIG. 4 is a pictorial representation of the information obtained from processing 3-D seismic data;

FIG. 5 is a pictorial representation of a horizontal time slice of 3-D seismic data processed in accordance with the prior art; and

FIG. 6 is a pictorial representation of a horizontal time slice of 3-D seismic data processed in accordance with the present invention.

Detailed Description

While this invention is susceptible of embodiment in many different forms, there is shown in the drawings, and will herein be described in detail, one specific embodiment of the invention. It should be understood, however, that the present disclosure is to be considered an exemplification of the principles of the invention and is not intended to limit the invention to the specific embodiment or algorithm so described.

The first step is to obtain a set of seismic data in the form of seismic signal traces distributed over a three dimensional volume of the earth.

Methods by which such data is obtained and reduced to digital form for processing as 3-D seismic data are well known to those skilled in the art.

The next step is to generate a "discontinuity cube." This is done by applying a coherency algorithm to the 3-D seismic data. This algorithm may take many forms. Whatever its form, its function is to compare the similarity of nearby regions of seismic data within the 3-D seismic volume. If a trace segment is similar to its neighbors (e.g., in the in-line and cross-line directions), it is assigned a low discontinuity value; if a trace segment is not similar to its neighbors, it is assigned a high discontinuity value.

FIG. 2 is a plan view of a portion of 3-D seismic volume. In order to measure discontinuity, a trace segment at one point A is compared to adjacent trace segments B and C. One way to compute trace similarity is described below.

The zero mean lagged cross-correlation in the in-line (x-direction) between trace u(t, x, y) and u(t, x+dx, y) with a lag time of "tlag" msec is defined as:

$$\rho_x\ (t, tlag) = \frac{\sum_{k=-w}^{k=+w} u(t+k, x, y)\, u(t+k+tlag, x+dx, y)}{\sqrt{a(t, x, y)\, a(t, x+dx, y)}}$$

where:

$$a(t,x,y) = \sum_{k=-w}^{k=+w} u^2(t+k, x, y)$$

and

$$a(t, x+dx, y) = \sum_{k=-w}^{k=+w} u^2(t+k, x+dx, y)$$

are autocorrelations used to normalize the cross-correlation, and where w+w is the length in msec of the correlation window. It is important to choose w large enough so the assumption of zero mean is valid. Values on the order of a seismic wavelet are appropriate. Other methods of normalization may be used (e.g., product of the energies of the traces, etc.). In particular, cross correlation is one method of combining two waveforms to

measure the similarities of the waveforms. Autocorrelation is a method of combining a waveform with itself. See Sheriff's "Encyclopedic Dictionary of Exploration Geophysics," Society of Exploration Geophysicists, Tulsa, Oklahoma.

The zero mean lagged cross-correlation in the cross-line (y-direction) between trace u(t, x, y) and u(t, x, y+dy) with a lag time of tlag msec is defined as:

$$\rho_x\ (t, tlag) = \frac{\sum_{k=-w}^{k=+w} u(t+k, x, y)\, u(t+k+tlag, x, y+dy)}{\sqrt{a(t, x, y)\, a(t, x, y+dy)}}$$

where

$$a(t, x, y+dy) = \sum_{k=-w}^{k=+w} u(t+k, x, y+dy)$$

The direction of apparent time dip in the x and y directions is estimated to be that lag (i.e., tlagx and tlagy) that has the greatest (i.e., most positive) cross-correlation. These values are ρ_x (t, tlagx) and ρ_y (t, tlagy).

Given the apparent dips (in msec/trace), it is a simple (but not necessarily accurate when dealing with noisy data) calculation to obtain dip and dip azimuth. More importantly, the concept of cross-correlation is extended to two dimensions by taking the geometric mean between the classical one dimensional cross-correlations:

$$\rho_{xy}\ (t, tlagx, tlagy) = \sqrt{\rho_x(t, tlagx)\ \rho_y(t, tlagy)}$$

This value (or attribute) serves as a rather robust estimate of signal discontinuity within geologic formations as well as signal discontinuities across faults and erosional unconformities.

Computer Program

A simplified FORTRAN 77 program for performing these calculations is given below:

Given a trace "x" from a 3-D seismic amplitude volume, and its two neighboring traces "y" (in the in-line direction) and "z" (in the cross-line

direction), subroutine COH calculates an output trace "rho" containing coherence coefficients using a running window cross-correlation algorithm where:

"mins" and "maxs" are the minimum and maximum sample indices for all four traces;

"inwinl" is the window length in samples;

"nlags" specifies the number of lags (relative time shifts) to do each side of "0" in the cross-correlation; and

"sr" is the sample interval in ms.

At each sample, subroutine CROSS calculates a series of normalized cross-correlation coefficients, returning the largest coefficients for each direction in "rho1" and "rho2". The time shift at which the maximum coefficients occur is returned in "tshf1" and "tshf2"; these times are not used. Subroutine COH is called repeatedly, once for every trace in the input seismic amplitude volume, to produce a new 3-D data volume or "coherency cube" containing coherence coefficients.

```
subroutine coh (x, y, z, rho, mins, maxs, iwinl, nlags, sr)
real x(mins:maxs), y(mins:maxs), z(mins:maxs)
real  rho(mins:maxs)

ihwin = iwinl/2

do j = mins+ihwin, maxs-ihwin
        k = j - ihwin
        call cross (x(k), iwinl, y(k), iwinl, nlags, sr, rho1, tshf1)
        call cross (x(k), iwinl, z(k), iwinl, nlags, sr, rho2, tshf2)
        rho(J) = sqrt (rho1*rho2)
enddo

return
end
```

```
subroutine cross (x, nx, y, ny, lags, sr, peak, tshift)
real   x(0:nx-1), y(0:ny-1), sr, peak, tshift
parameter   (maxlags=128)
```

```
real  g(-maxlags:+maxlags)
double precision xx,yy

nlags = max(0, min(lags, maxlags))
tshift = 0.0
peak = 0.0
xx = 0.0
yy = 0.0
ks = 0

do ix = 0, nx-1
     xx = x(ix)**2+xx
enddo

if  (xx .eq. 0.0) return

do iy = 0, ny-1
    yy = y(iy)**2 + yy
enddo

if (yy .eq. 0.0) return

do is =  -nlags, + nlags
    g(is) = 0.0
    do it = 0, nx-1
         if (it-is .ge. 0) then
            if (it-is  .le.  ny-1) then
               g(is) = g(is) + x(it)*y(it-is)
            endif
         endif
    enddo
      if (abs(peak)  .lt.  abs(g(is)))  then
         peak = g(is)
         ks = is
      endif
enddo

tshift = ks*sr
```

```
peak = peak/sqrt (xx*yy)

return

end
```

Landmark and GeoQuest interpretive workstations, for example, can be used to view and interpret faults and stratigraphic features by loading the discontinuity cube as a seismic volume. Visualization software (e.g., Landmarks's SeisCube software) may be employed to rapidly slice through the discontinuity volume to aid in understanding complex fault relationships. Discontinuity displays can reduce interpretation cycle time when used in selecting which seismic lines to interpret, enabling the interpreter to work around faults and poor data areas. In addition, subtle stratigraphic features and complex faulting which are not readily apparent on traditional seismic displays can be rapidly identified and interpreted. FIG's. 5 and 6 are side by side comparisons of the same seismic information displayed and processed conventionally and in accordance with the present invention. Fault lines are readily apparent in FIG. 6.

Coherency maps have been run on several 3-D surveys. At depths of reasonable data quality, approximately 90% of the faults can be readily identified. Faults were identified on coherency maps which were very subtle on seismic sections, but clearly present on the coherency maps because of the robustness of the method and the map perspective of fault patterns. Since coherency maps can be run on uninterpreted time slices, the present invention offers a means to greatly accelerate mapping of the structural framework and to reveal details of fault relationships which would otherwise be interpreted only through tedious fault picking.

<u>Specific Examples</u>

2-D seismic coherence maps were generated along picked horizons and clearly identified shale diapirs in offshore Nigeria.

In offshore Gulf of Mexico, the technique readily identified diapiric structures.

On several coherence time slices, remarkable detail of stratigraphic features, such as abandoned river channels, mud

flows, and submarine canyons, was displayed. On seismic sections, these features were sometimes apparent but, in some cases, were unidentifiable even with close scrutiny.

This is the first known method of revealing fault planes within a 3-D volume where no fault reflections have been recorded. Faults are often critical to the accumulation of oil. A fault may form a seal by cutting off a structural or stratigraphic feature so the oil is trapped against the fault. On the other hand, if the fault plane contains rubble that has not been cemented, it may form a conduit for fluids. This may allow the hydrocarbons to drift up the fault plane into the feature and be trapped in it or to escape from the feature by drifting up the fault plane out of it.

Thus, fault lines can predict flow patterns in a reservoir and communication between injector and producing wells, for example. Seismic discontinuities can also provide the needed link to enable reservoir prediction between the wells and establish reservoir continuity and flow patterns across a field.

Coherency mapping of 3-D seismic is an extremely powerful and efficient tool for mapping both structure and stratigraphy. The new method is particularly sensitive to any lateral variation in wavelet character and therefore is particularly sensitive to the common causes of lateral variations in the wavelet (i.e., fault displacement or stratigraphic variations). This 3-D method analyzes a time-slice or horizon based interval and measures the maximum of the normalized cross-correlation in the in-line and cross-line directions.

Further Analysis

The discontinuity cube will clearly highlight fault planes as zones of high discontinuity. However, these zones may not be clearly in areas of lower signal-to-noise ratio. A method of enhancing these fault zones involves the application of a "median planar operator." Faults in the earth's subsurface generally express themselves as planes or surfaces. In the case of a curved fault surface, a series of small flat planes may be used to approximate the fault surface. In accordance with this aspect of the invention, a small planar operator is used to enhance (i.e., a "filter") the identification of subtle stratigraphic features. First, a small region of seismic data is selected around a center value. This region may be formed from a plurality of the cells used to form the "coherency cube." A small fault plane is then mathematically inserted into the region, and the median value of the

points within the plane is calculated for the dip and azimuth that best aligns with the zone of high discontinuity. This median value is then assigned to the center value of a new array. Next, the region of data is shifted (e.g., by one row) and the process is repeated until each point in the previously determined discontinuity cube has been analyzed as a center value. The end result is a completely new discontinuity cube with fault planes enhanced and noise and stratigraphic features (i.e., non-planar features) attenuated. These stratigraphic features may be separated by subtracting the new discontinuity cube from the old discontinuity cube without the planar filter application.

From the foregoing description, it will be observed that numerous variations, alternatives and modifications will be apparent to those skilled in the art. Accordingly, this description is to be construed as illustrative only and is for the purpose of teaching those skilled in the art the manner of carrying out the invention. Other algorithms may be used to measure the similarity of nearly regions of seismic data or to generate the "discontinuity cube." Moreover, equivalent computations may be substituted for those illustrated and described. Also certain features of the invention may be used independently of other features of the invention.

For example, stratigraphic features have been generally identified on time slices where dips were low; and consequently, the time window captured a narrow statigraphic section. In areas of higher dip, the method should work on picked horizons. Therefore, as a stratigraphic mapping tool, there is good reason to believe that new levels of detail can be mapped than previously, although this may require mapping of the horizon of interest.

As another example, while coherence slice maps by themselves are very powerful mapping tools, when used in conjunction with reconnaissance mapping of amplitudes and dip maps, there is promise of a technological milestone in mapping effectiveness for the Gulf of Mexico or similar basins with 3-D seismic. It is believed that detailed mapping of structure and stratigraphy will be accelerated by mapping in a map view and less by traditional line by line picking. Interpretation in a map view of "reconnaissance" data offers significant improvement in quality and quantity of interpretation.

Thus it will be appreciated that various modifications, alternatives, variations, and changes may be made without departing from the spirit and scope of the invention as defined in the appended claims. It is, of course,

intended to cover by the appended claims all such modifications involved within the scope of the claims.

CLAIMS

We claim:

1. A method for the exploration of hydrocarbons, comprising the steps of:

a) obtaining a set of seismic signal traces distributed over a pre-determined three-dimensional volume of the earth;

b) dividing said three-dimensional volume into a plurality of vertically stacked and generally spaced apart horizontal slices and dividing at least one of said slices into a plurality of cells that are arranged into laterally extending rows and columns, each of said cells having portions of at least three seismic traces located therein, each of said portions of said traces generally extending vertically through said cells, and a first trace and a second trace in said cell lying in one generally vertical plane and a third trace and said first trace in said cell lying in another generally vertical plane that is generally at right angles to said one vertical plane;

c) measuring across each of said cells the cross-correlation between said traces lying in said one vertical plane to obtain an in-line value and the cross-correlation between said traces lying in said another vertical plane to obtain a cross-line value that are estimates of the time dip in an in-line direction and in a cross-line direction;

d) combining said in-line value and said cross-line value to obtain one coherency value for each of said cells; and

e) displaying said coherency values of said cells across at least one of said horizontal slices.

2. The method of Claim 1, wherein step (b) is performed on each of said horizontal slices; and where in step (e) said coherency values are displayed over successive horizontal slices.

3. The method of Claim 1, wherein step (c) includes the step of normalizing each in-line value and each cross-line value.

4. The method of Claim 3, wherein said step of normalizing includes the step of obtaining the product of the energies of each pair of traces.

5. The method of Claim 3, wherein the auto-correlation of said traces lying in said one vertical plane and the auto-correlation of said traces lying in said another vertical plane are obtained to normalize said cross-correlations in the in-line direction and in the cross-line direction.

6. The method of Claim 1, wherein step (c) comprises the steps of computing the zero mean lagged cross-correlation in said in-line direction, and computing the zero mean lagged cross-correlation in said cross-line direction.

7. The method of Claim 6, wherein step (d) comprises the steps of identifying the most positive value of said zero mean lagged cross-correlation in said in-line direction, and identifying the most positive value of said zero mean lagged cross-correlation in the cross-line direction.

8. The method of Claim 7, wherein step (d) comprises the step of computing the geometric mean between said two most positive values.

9. The method of Claim 1, where in step (a) said set of seismic signal traces comprises a plurality of amplitude-versus-horizontal coordinate-and-time traces of seismic data.

10. The method of Claim 1, where in step (a) said signal traces are digitally formatted.

11. The method of Claim 1, wherein each of said horizontal slices of step (b) extends over about 100 milliseconds.

12. A method of locating subterranean features, faults, and contours, comprising the steps of:

a) obtaining 3-D seismic data covering a pre-determined volume of the earth;

b) dividing said volume into an array of relatively small three-dimensional cells wherein each of said cells is characterized by at least three laterally separated and generally vertical seismic traces located therein;

c) measuring in each said cells the coherency/similarity of said at least three traces relative to two pre-determined directions; and

d) displaying said coherency/similarity of said cells to form a two-dimensional map of subterranean features.

13. The method of Claim 12, where in step (c) said pre-determined directions are mutually perpendicular; and wherein said coherency/similarity of said cells is measured as a function of the cross-correlation between two traces in one direction and the cross-correlation between two traces in a direction that is perpendicular to said one direction.

14. The method of Claim 13, wherein said coherency/similarity of said cells is measured as a function of the greatest cross-correlation in each of said two directions.

15. The method of Claim 14, wherein said coherency/similarity is proportional to the geometric mean of said two greatest cross-correlations.

16. The method of Claim 12, further including the step of:

e) displaying the coherencies/similarities of successive vertically separated horizontal arrays of three-dimensional cells to identify relative space and time invarient features.

17. The method of Claim 12, further including the steps of:

e) selecting at least one two-dimensional pre-determined contour;

f) dividing said contour into at least one flat two-dimensional surface;

g) locating said one two-dimensional surface within a plurality of three-dimensional groups of said cells;

h) measuring the median of the coherency/similarity of each group of cells relative to said one two-dimensional surface;

i) relocating said one two-dimensional surface in said group of cells and remeasuring said median of said coherency/similarity to find a location in each group where said median is a maximum; and

j) assigning said maximum coherency/similarity of each group of cells to one location within said group of cells.

18. The method of Claim 17, further including the steps of:

k) obtaining the difference between the values obtained in step (c) and step (j); and

l) displaying said difference in coherency/similarity values to identify subterranean shapes generally the same as said pre-determined contour in preference to other shapes.

19. A method of prospecting for hydrocarbon deposits, comprising the steps of:

a) obtaining stacked seismic signal amplitude data traces over at least three pre-determined three-dimensional volumes of the earth, at least one of said volumes having a known hydrocarbon deposit;

b) dividing each of said volumes into an array of relatively small three-dimensional cells, wherein each of said cells has at least three laterally separated seismic traces located therein;

c) measuring in each of said cells the coherency values of said seismic traces;

d) comparing coherency values of said one volume having a known hydrocarbon deposit to the coherency values of the other three-dimensional volumes; and

e) drilling into a location in one of said two volumes having coherency values comparable to the coherency values of said one volume.

20. The method of Claim 19, where in step (d), the most positive coherency values are identified and compared.

21. The method of Claim 19, wherein step (c) includes the steps of:

(i) measuring in each of said cells the cross-correlation between one pair of traces relative to one vertical plane to obtain an in-line value and measuring the cross-correlation between another pair traces relative to another vertical plane to obtain a cross-line value; and

(ii) combining said in-line value and said cross-line value to obtain a coherency value for said cell.

22. The method of Claim 21, wherein said coherency value is assigned to the center of said cell.

23. The method of Claim 19, where in step (d) in each volume the coherency values assigned to the cells of one generally horizontal plane are compared to the coherency values of an adjacent horizontal plane.

24. The method of Claim 19, wherein step (c) includes the steps of computing normalized cross-correlations of adjacent seismic traces in each of said cells, and identifying the greatest of said normalized cross-correlations.

25. In seismic exploration wherein the amplitudes of reflected seismic energy are recorded as a function of time to produce a series of seismic traces, a method comprising the steps of:

(a) acquiring 3-D seismic data over a predetermined volume having at least one of a geological formation, fault and an erosional unconformity;

(b) comparing the similarity of nearby regions of seismic data of said volume by:

(i) determining the zero mean lagged cross-correlation in the in-line direction between a first trace and a second trace and determining the zero mean lagged cross-correlation in the cross-line direction, between said first trace and a third trace,

(ii) identifying the most positive of said zero mean lagged cross-correlations in said in-line direction and in said cross-line direction;

(iii) determining the geometric mean of said most positive zero mean lagged cross-correlation in the in-line direction and said zero mean lagged cross-correlation in the cross-line direction; and

(iv) repeating steps (i) through (iii) for substantially all of the traces comprising said 3-D seismic data; and

(c) displaying said geometric mean values to identify at least one of a geological formation, a fault and an erosional unconformity.

26. The method of Claim 25, further including the steps of: applying a median planar operator to a plurality of said geometric mean values to find the dip and dip azimuth of a plane that best aligns with a zone of high signal discontinuity within said volume.

 SUBSTITUTE SHEET (RULE 26)

27. A method of seismic exploration, comprising the steps of:

a) obtaining a 3-D seismic data set comprising seismic signal traces distributed over a volume of the earth;

b) dividing said volume into spaced apart horizontal slices and dividing each slice into cells that are arranged into laterally extending rows and columns, each of said cells having three seismic traces that generally extend vertically through said cells and in two generally vertical mutually perpendicular planes;

c) computing in each cell the cross-correlation between said traces lying in said one vertical plane to obtain an in-line value and the cross-correlation between said traces lying in said another vertical plane to obtain a cross-line value;

d) computing a coherency value for each of said cells, said coherency value being representative of the geometric mean of the most positive value of said cross-correlation in said in-line direction and the most positive value of said cross-correlation in the cross-line direction; and

e) displaying said coherency values of said cells across at least one of said horizontal slices.

AMENDED CLAIMS

[received by the International Bureau on 24 May 1996(24.05.96) ; original claims 17-25 and 27 cancelled; claim 26 amended and renumbered as claim 17; claim 28 renumbered as claim 22, new claims 18-21 and 22-55 added (10 pages)]

d) displaying said coherency/similarity of said cells to form a two-dimensional map of subterranean features.

13. The method of Claim 12, where in step (c) said pre-determined directions are mutually perpendicular; and wherein said coherency/similarity of said cells is measured as a function of the cross-correlation between two traces in one direction and the cross-correlation between two traces in a direction that is perpendicular to said one direction.

14. The method of Claim 13, wherein said coherency/similarity of said cells is measured as a function of the greatest cross-correlation in each of said two directions.

15. The method of Claim 14, wherein said coherency/similarity is proportional to the geometric mean of said two greatest cross-correlations.

16. The method of Claim 12, further including the step of:

e) displaying the coherencies/similarities of successive vertically separated horizontal arrays of three-dimensional cells to identify relative space and time invarient features.

17. In seismic exploration wherein 3-D seismic data comprising reflected seismic energy is recorded as a function of time to produce a series of seismic traces and wherein a computer is used that is adapted to process such seismic traces, an article of manufacture comprising:

a medium that is readable by a computer and that carries instructions for said computer to perform a process comprising the steps of:

(a) accessing 3-D seismic data over a predetermined volume;

(b) comparing the similarity of nearby regions of said 3-D seismic data of said volume by:

(i) dividing said volume into at least one horizontal slice and dividing said at least one slice into a plurality of cells that are arranged into laterally extending rows and columns, each of said cells having portions of at least three seismic traces extending therethrough including a first trace and a second trace that lie in one plane and a third trace that with said first trace lies in another plane that is gen rally at right angles to said one plane;

AMENDED SHEET (ARTICLE 19)

(ii) m asuring across each of said cells the coherency of said traces lying in said one plane to obtain a first coherency value and measuring the coherency of said traces lying in said another plane to obtain a second coherency value;

(iii) combining said first coherency value and said second coherency value in each cell to obtain one coherency value that is representative of the coherency of said seismic traces in said cell; and

(iv) storing said one coherency value of each cell of said at least one horizontal slice in a form for displaying said combined coherency values as a seismic attribute map .

18. The article of manufacture of claim 17, wherein said medium carries instructions for said computer to perform step (ii) by determining the cross-correlation between said first trace and said second trace, and determining the cross-correlation between said first trace and said third trace.

19. The article of manufacture of claim 18, wherein said medium carries instructions for said computer to perform step (ii) by determining the zero mean lagged cross-correlation between said first trace and said second trace, and determining the zero mean lagged cross-correlation between said first trace and said third trace.

20. The article of manufacture of claim 19, wherein said medium carries instructions for said computer to perform step (iii) by identifying the most positive of each of said zero mean lagged cross-correlations.

21. The article of manufacture of claim 20, wherein said medium carries instructions for said computer to perform step (iii) by further determining the geometric mean of said two most positive zero mean lagged cross-correlations.

22. A method of seismic exploration, comprising the st ps of:

a) obtaining a 3-D s ismic data set comprising seismic signal traces distributed over a volume of the earth;

b) dividing said volume into spaced apart horizontal slices and dividing each slice into cells that are arrang d into laterally extending

rows and columns, each of said cells having at least three seismic traces that generally lie in two generally vertical and mutually perpendicular planes;

c) computing in each cell the cross-correlation between said traces lying in said one vertical plane to obtain an in-line value and the cross-correlation between said traces lying in said another vertical plane to obtain a cross-line value;

d) computing a coherency value for each of said cells, said coherency value being representative of a mean of the most positive value of said cross-correlation in said in-line direction and the most positive value of said cross-correlation in the cross-line direction; and

e) displaying said coherency values of said cells across at least one of said horizontal slices.

23. An apparatus, comprising:

a) recorded means readable by a computer and carrying instructions for a process comprising the steps of:

(1) accessing data comprising seismic signal traces distributed over a pre-determined three-dimensional volume of the earth;

(2) arranging said three-dimensional volume into a plurality of vertically stacked horizontal slices and arranging at least one of said slices into a plurality of cells that are arranged into laterally extending rows and columns, each of said cells having portions of at least three seismic traces located therein, each of said portions of said traces generally extending through said cells, and a first trace and a second trace in said cell lying in one plane and a third trace and said first trace in said cell lying in another plane that is generally at an angle to said one plane;

(3) computing in each of said cells the cross-correlation between said traces lying in said one plane to obtain an in-line value and computing the cross-correlation between said traces lying in said another plane to obtain a cross-line value; and

(4) combining said in-line value and said cross-line value to obtain a coherency value for each of said cells.

24. Th apparatus of Claim 23, wherein step (3) further includes the steps of: obtaining the auto-correlation of said trac s lying in said one plane; and obtaining the auto-correlation of said traces lying in said another plane to normalize said cross-correlations in said in-line direction and in said cross-line direction.

 AMENDED SHEET (ARTICLE 19)

25. The apparatus of Claim 23, wherein step (4) comprises the steps of: computing the zero mean lagged cross-correlation in said in-line direction; and computing the zero mean lagged cross-correlation in said cross-line direction.

26. The apparatus of Claim 25, wherein step (4) comprises the steps of: identifying the most positive value of said zero mean lagged cross-correlation in said in-line direction; and identifying the most positive value of said zero mean lagged cross-correlation in said cross-line direction.

27. The apparatus of Claim 26, wherein step (4) comprises the step of computing a mean of said two most positive values.

28. In a computer adapted to receive 3-D seismic data and having a display for depicting processed 3-D seismic data, an article of manufacture comprising:

a) a medium that is readable by the computer and that carries instructions for the computer to perform a process comprising the steps of:

(1) arranging the 3-D data into a plurality of cells that are arranged into laterally extending rows and columns, each of said cells having portions of at least three seismic traces located therein, including a first trace and a second trace that lie in one plane and including a third trace that with said first trace lies in another plane that is at an angle to said one plane;

(2) calculating in said cells representations of the cross-correlation between said traces lying in said one plane and calculating representations of the cross-correlation between said traces lying in said another plane; and

(3) combining said representations of the cross-correlation between said traces lying in said one plane and said representations of the cross-correlation between said traces lying in said another plane to obtain one coherency value for ach of said c lls.

29. The article of manufacture of Claim 28, wherein said medium carries instructions for the computer to perform step (3) by combining a

representation of the greatest cross-correlation in said one plane and a representation of the gr at st cross-correlation in said another plane.

30. The article of manufacture of Claim 29, wherein said medium carries instructions for the computer to combine said representations of the greatest cross-correlation in said one plane and the greatest cross-correlation in said another plane by calculating a representation of a mean of said two greatest cross-correlations.

31. In a computer having stored therein 3-D seismic data that covers a pre-determined volume of the earth, a device that is readable by the computer and that carries instructions to perform a process comprising the steps of:

(1) digitally sorting said data into an array of relatively small three-dimensional cells wherein each of said cells is characterized by at least three laterally separated and generally vertical seismic traces located therein;

(2) calculating in each said cells a coherency value from said at least three traces relative to two pre-determined directions; and

(3) storing said coherency values of said cells for the computer to display a two-dimensional map of subterranean features represented by said coherency values.

32. The device of Claim 31, where in step (2) said two pre-determined directions are mutually perpendicular; and wherein each coherency value is calculated as a function of the cross-correlation between two traces in one of said two mutually perpendicular directions and the cross-correlation between two traces in the other of said two mutually perpendicular directions.

33. The device of Claim 32, wherein said coherency value of step (2) is computed as a function of the greatest cross-correlation in said one direction and the greatest cross-correlation in said other direction.

34. The device of Claim 33, wherein said coherency value of step (2) is a function of the geometric mean of said two greatest cross-correlations.

35. A method of prospecting for hydrocarbon deposits, comprising the st ps of:

a) obtaining 3-D seismic data over a pre-determined three-dimensional volume of the earth;

b) using a computer and a program for said computer that instructs said computer to perform the following steps:

(1) reading said data and dividing said volume into an array of relatively small three-dimensional cells, wherein each of said cells has at least three laterally separated seismic traces located therein; and

(2) calculating in each of said cells coherency values of said seismic traces; and

c) using said computer to display said coherency values; and

d) using said display to identify geological features and locations that are indicative of the location of an oil or gas deposit.

36. The method of Claim 35, further including the step of

e) drilling a well at a location identified in step (d).

37. The method of Claim 35, wherein step (2) is performed by:

(i) measuring the cross-correlation between one pair of traces relative to one vertical plane to obtain an in-line value and measuring the cross-correlation between another pair traces relative to another vertical plane to obtain a cross-line value; and

(ii) combining said in-line value and said cross-line value to obtain a coherency value for said cell.

38. The method of Claim 37, wherein step (ii) includes the steps of: identifying a maximum in-line cross-correlation and a maximum cross-line cross-correlation; and combining said maximum cross-correlations.

39. The method of Claim 38, wherein said maximum cross correlations are combined by computing their mean.

40. A device, comprising:

a) a recording that is readable by a computer and that carries instructions for a process comprising th steps of:

(1) reading data representative of seismic signal traces distributed over a pre-determined three-dimensional volume of the earth;

(2) sorting said signal traces by dividing said three-dimensional volume into a plurality of relatively thin cells that are arranged into laterally extending rows and columns, each of said cells having portions of at least three seismic traces located therein, including a first trace and a second trace that be in one plane and a third trace that lies with said first trace in another plane that is at an angle to said one plane;

(3) measuring in each of said cells the cross-correlation between said traces lying in said one plane to obtain an in-line value and the cross-correlation between said traces lying in said another plane to obtain a cross-line value; and

(4) combining said in-line value and said cross-line value to obtain one coherency value for each of said cells.

41. The device of Claim 40, wherein the computer includes means for displaying said coherency values of said cells.

42. The device of Claim 40, wherein step (4) comprises the steps of: computing the zero mean lagged cross-correlation in said in-line direction; and computing the zero mean lagged cross-correlation in said cross-line direction.

43. The device of Claim 42, wherein step (4) comprises the steps of: identifying the most positive value of said zero mean lagged cross-correlation in said in-line direction; and identifying the most positive value of said zero mean lagged cross-correlation in the cross-line direction.

44. The device of Claim 43, wherein step (4) comprises the step of computing a mean between said two most positive values.

45. A method of locating subterranean features, faults, and contours, comprising the steps of:

a) obtaining seismic data covering a pre-determined volume of the earth;

b) dividing said volume into an array of relatively small three-dimensional cells wherein each of said cells is characterized by at least three laterally separated and generally vertical seismic traces located therein;

c) measuring in each said cells the cross-correlation between two traces in one direction and the cross-correlation between two traces in a direction that is perpendicular to said one direction; and

d) displaying a representation of said cross-correlation between two traces in one direction and said cross-correlation between two traces in a direction that is perpendicular to said one direction in the form a two-dimensional map.

46. The method of Claim 45, wherein said representation of step (d) is a function of the greatest cross-correlation in each of said two directions.

47. The method of Claim 45, wherein said representation of step (d) is a function of the geometric mean of said two cross-correlation.

48. A method of prospecting for hydrocarbon deposits, wherein 3-D seismic data is obtained over a pre-determined three-dimensional volume of the earth, wherein a computer reads the data and divides the volume into an array of relatively small three-dimensional cells, wherein each cell has at least three laterally separated seismic traces located therein, wherein the computer is used to transform the data into a display of seismic attributes, wherein computer is used to make a map of seismic attributes, and wherein the map is used to identify subsurface features commonly associated with the entrapment and storage of hydrocarbons, **characterized by**:

(1) calculating in each of the cells a coherency value for said seismic traces; and

(2) displaying the coherency value of each cell that lies between two planes within the 3-D volume.

49. The method of Claim 48, wherein step (1) is performed by:

(i) measuring in each cell the cross-correlation between one pair of traces relative to one vertical plane to obtain an in-line value and measuring the cross-correlation between another pair traces relative to anoth r vertical plane to obtain a cross-line value; and

(ii) combining said in-line value and said cross-line value to obtain a coherency valu for said cell.

50. The method of Claim 49, wherein each cell contains a plurality of traces in each vertical plane; wherein step (i) is performed for all traces in each vertical plane; and wherein step (ii) comprises the steps of: identifying a maximum in-line cross-correlation and a maximum cross-line cross-correlation; and combining said maximum in-line and said maximum cross-line cross-correlations.

51. A seismic map prepared by a process, comprising the steps of:

(1) accessing, by means of a computer, a dataset comprising seismic signal traces distributed over a pre-determined three-dimensional volume of the earth;

(2) dividing said three-dimensional volume into a plurality of vertically stacked slices and dividing at least one of said slices into a plurality of cells that are arranged into laterally extending rows and columns, each of said cells having portions of at least three seismic traces located therein, each of said portions of said traces generally extending through said cells, and a first trace and a second trace in each cell lying in one plane and a third trace and said first trace in said cell lying in another plane that is generally at an angle to said one plane;

(3) computing across each cell the cross-correlation between said traces lying in said one plane to obtain an in-line value and computing the cross-correlation between said traces lying in said another plane to obtain a cross-line value;

(4) combining said in-line value and said cross-line value to obtain one coherency value for each cell; and

(5) displaying said coherency values of said c lls across at least one of said slices.

52. The seismic map of Claim 51, wherein prior to step (5) said coherency values of said cells are digitally stored in a memory; and wherein step (5) is performed by printing out said coherency values in the form of an image representative of the subsurface.

53. The seismic map of Claim 51, wherein step (3) comprises the steps of: computing the zero mean lagged cross-correlation in said in-line direction; and computing the zero mean lagged cross-correlation in said cross-line direction.

54. The seismic map of Claim 53, wherein step (4) comprises the steps of: identifying the most positive value of said zero mean lagged cross-correlation in said in-line direction; identifying the most positive value of said zero mean lagged cross-correlation in the cross-line direction; and combining said two most positive values.

55. The seismic map of Claim 54, where in step (4) said two most positive values are combined by computing their geometric mean.

AMENDED SHEET (ARTICLE 19)

Statement under Article 19(1)

Proper protection of the invention requires that claims should be included not only for the process described by the claims but also for the steps of the process when recorded on computer readable media and the product (a seismic map) of the process. Accordingly, claims have been added to cover computer media having instructions for performing the process of the invention and the product of the process.

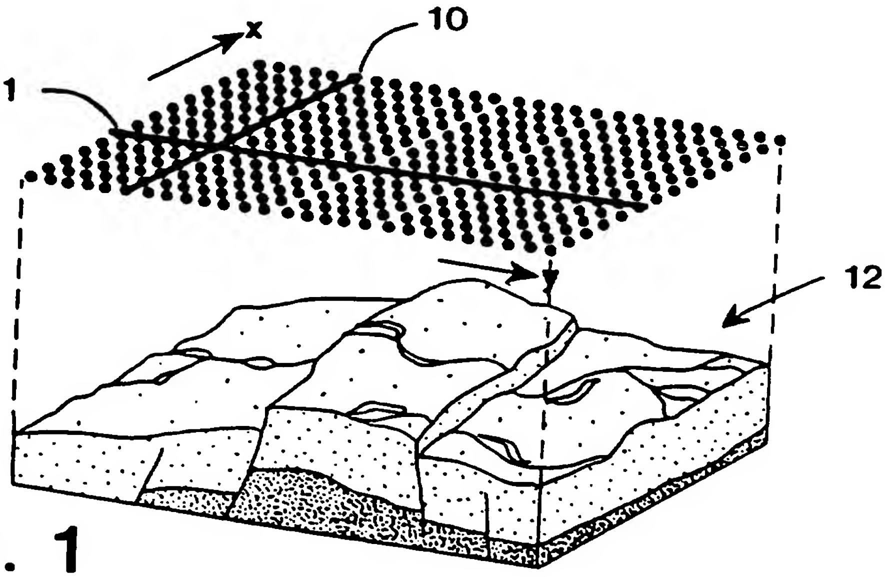

FIG. 1

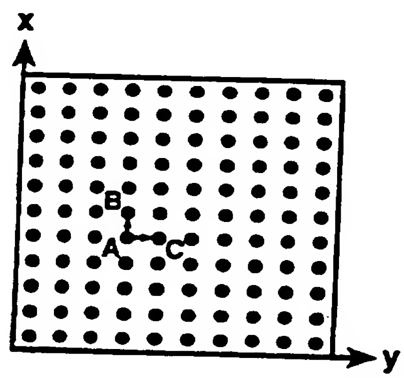

FIG. 2

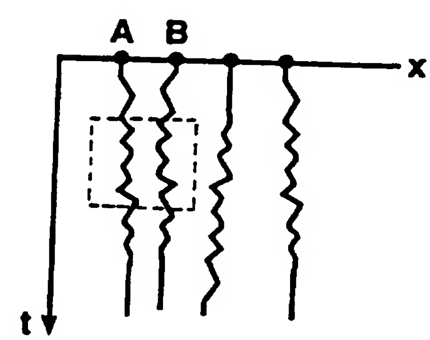

FIG. 3

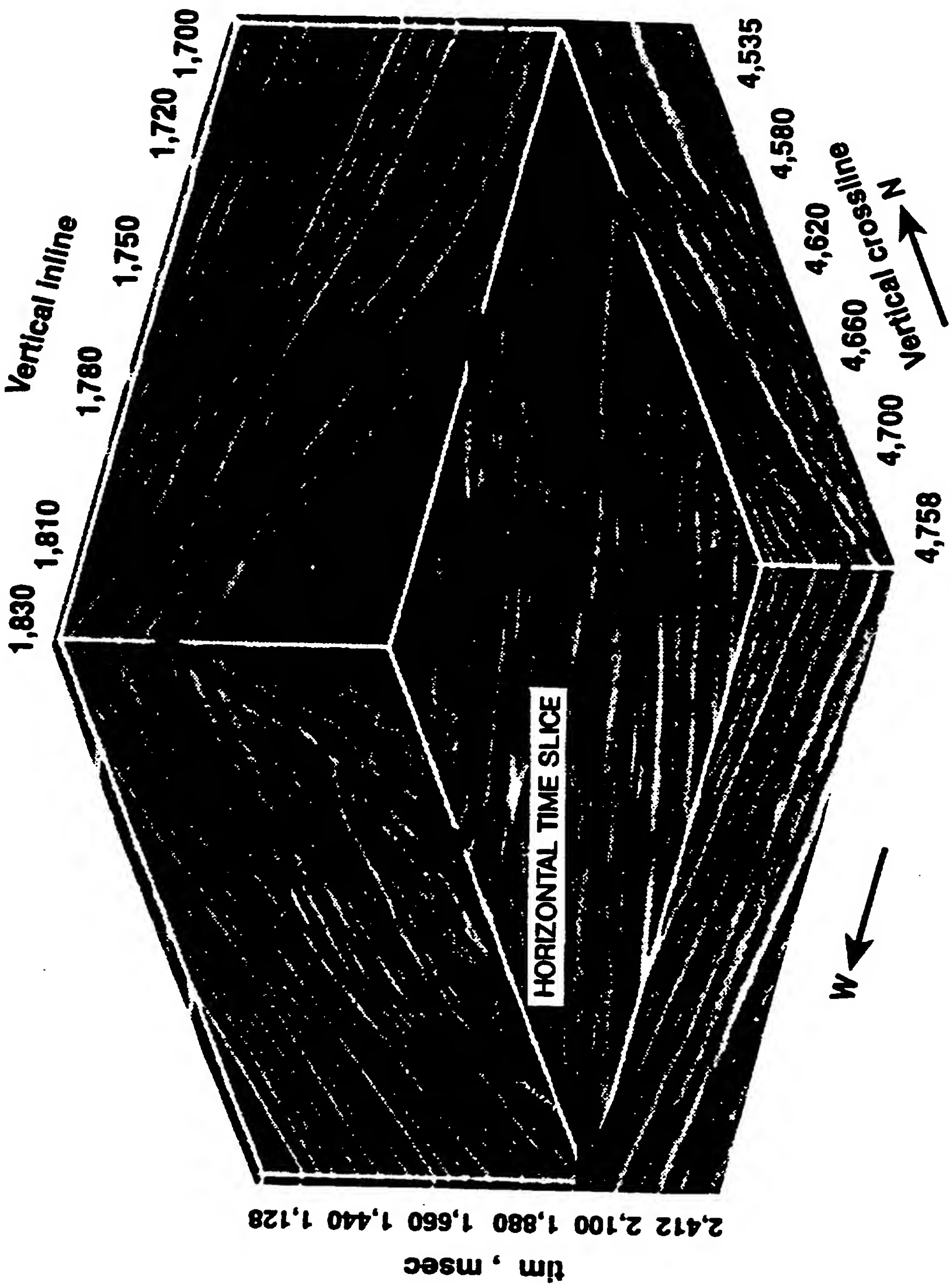
Vertical inline
1,700
1,720
1,750
1,780
1,810
1,830
4,535
4,580
4,620
4,660
4,700
4,758
Vertical crossline
N
W
HORIZONTAL TIME SLICE
2,412 2,100 1,880 1,660 1,440 1,128
tim , msec

FIG. 4

FIG. 5

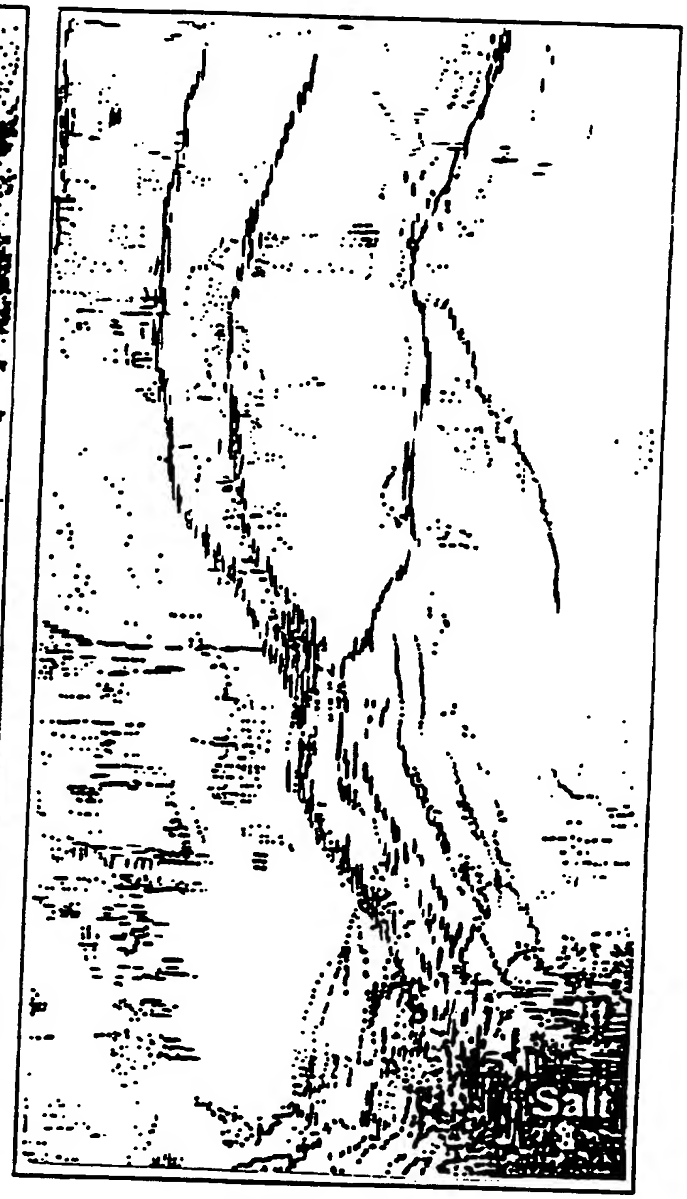

FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 95/13644

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01V1/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,5 056 066 (HOWARD ROBERT E) 8 October 1991 see abstract ---	1
A	US,A,5 153 858 (HILDEBRAND HAROLD A) 6 October 1992 see abstract ---	1
A	EP,A,0 181 216 (TEXAS INSTRUMENTS INC) 14 May 1986 see abstract -----	1

[ ] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 March 1996	27.03.96

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Anderson, A

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 95/13644

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A-5056066	08-10-91	AT-T-	127237	15-09-95
		AU-B-	8051691	23-01-92
		CA-A-	2064686	26-12-91
		DE-D-	69112580	05-10-95
		EP-A-	0489135	10-06-92
		WO-A-	9200532	09-01-92
US-A-5153858	06-10-92	AT-T-	129577	15-11-95
		CA-A-	2088501	10-01-93
		CN-A,B	1070267	24-03-93
		DE-D-	69205673	30-11-95
		EP-A-	0548341	30-06-93
		EP-A-	0652447	10-05-95
		US-A-	5432751	11-07-95
		WO-A-	9301508	21-01-93
		US-A-	5251184	05-10-93
EP-A-0181216	14-05-86	US-A-	4672546	09-06-87
		US-A-	4633402	30-12-86
		US-A-	4703426	27-10-87
		US-A-	4633401	30-12-86
		CA-A-	1249876	07-02-89
		US-A-	4727488	23-02-88

VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS

PCT

INTERNATIONALER RECHERCHENBERICHT

(Artikel 18 sowie Regeln 43 und 44 PCT)

Aktenzeichen des Anmelders oder Anwalts 0497.13	**WEITERES VORGEHEN**	siehe Mitteilung über die Übermittlung des internationalen Recherchenberichts (Formblatt PCT/ISA/220) sowie, soweit zutreffend, nachstehender Punkt 5
Internationales Aktenzeichen PCT/DE 00/ 02000	Internationales Anmeldedatum *(Tag/Monat/Jahr)* 15/06/2000	(Frühestes) Prioritätsdatum *(Tag/Monat/Jahr)* 19/07/1999
Anmelder TRAPPE, Henning et al.		

Dieser internationale Recherchenbericht wurde von der Internationalen Recherchenbehörde erstellt und wird dem Anmelder gemäß Artikel 18 übermittelt. Eine Kopie wird dem Internationalen Büro übermittelt.

Dieser internationale Recherchenbericht umfaßt insgesamt 2 Blätter.

[X] Darüber hinaus liegt ihm jeweils eine Kopie der in diesem Bericht genannten Unterlagen zum Stand der Technik bei.

1. **Grundlage des Berichts**

   a. Hinsichtlich der **Sprache** ist die internationale Recherche auf der Grundlage der internationalen Anmeldung in der Sprache durchgeführt worden, in der sie eingereicht wurde, sofern unter diesem Punkt nichts anderes angegeben ist.

   [ ] Die internationale Recherche ist auf der Grundlage einer bei der Behörde eingereichten Übersetzung der internationalen Anmeldung (Regel 23.1 b)) durchgeführt worden.

   b. Hinsichtlich der in der internationalen Anmeldung offenbarten **Nucleotid– und/oder Aminosäuresequenz** ist die internationale Recherche auf der Grundlage des Sequenzprotokolls durchgeführt worden, das

   [ ] in der internationalen Anmeldung in Schriflicher Form enthalten ist.
   [ ] zusammen mit der internationalen Anmeldung in computerlesbarer Form eingereicht worden ist.
   [ ] bei der Behörde nachträglich in schriftlicher Form eingereicht worden ist.
   [ ] bei der Behörde nachträglich in computerlesbarer Form eingereicht worden ist.
   [ ] Die Erklärung, daß das nachträglich eingereichte schriftliche Sequenzprotokoll nicht über den Offenbarungsgehalt der internationalen Anmeldung im Anmeldezeitpunkt hinausgeht, wurde vorgelegt.
   [ ] Die Erklärung, daß die in computerlesbarer Form erfaßten Informationen dem schriftlichen Sequenzprotokoll entsprechen, wurde vorgelegt.

2. [ ] **Bestimmte Ansprüche haben sich als nicht recherchierbar erwiesen** (siehe Feld I).

3. [ ] **Mangelnde Einheitlichkeit der Erfindung** (siehe Feld II).

4. Hinsichtlich der **Bezeichnung der Erfindung**

   [X] wird der vom Anmelder eingereichte Wortlaut genehmigt.
   [ ] wurde der Wortlaut von der Behörde wie folgt festgesetzt:

5. Hinsichtlich der **Zusammenfassung**

   [X] wird der vom Anmelder eingereichte Wortlaut genehmigt.
   [ ] wurde der Wortlaut nach Regel 38.2b) in der in Feld III angegebenen Fassung von der Behörde festgesetzt. Der Anmelder kann der Behörde innerhalb eines Monats nach dem Datum der Absendung dieses internationalen Recherchenberichts eine Stellungnahme vorlegen.

6. Folgende Abbildung der **Zeichnungen** ist mit der Zusammenfassung zu veröffentlichen: Abb. Nr. 1

   [ ] wie vom Anmelder vorgeschlagen
   [X] weil der Anmelder selbst keine Abbildung vorgeschlagen hat.
   [ ] weil diese Abbildung die Erfindung besser kennzeichnet.

   [ ] keine der Abb.

INTERNATIONALER RECHERCHENBERICHT

Intern[redacted]ales Aktenzeichen
PCT[redacted]00/02000

A. KLASSIFIZIERUNG DES ANMELDUNGSGEGENSTANDES
IPK 7 G01V1/28

Nach der Internationalen Patentklassifikation (IPK) oder nach der nationalen Klassifikation und der IPK

B. RECHERCHIERTE GEBIETE

Recherchierter Mindestprüfstoff (Klassifikationssystem und Klassifikationssymbole)
IPK 7 G01V

Recherchierte aber nicht zum Mindestprüfstoff gehörende Veröffentlichungen, soweit diese unter die recherchierten Gebiete fallen

Während der internationalen Recherche konsultierte elektronische Datenbank (Name der Datenbank und evtl. verwendete Suchbegriffe)

EPO-Internal, INSPEC, COMPENDEX

C. ALS WESENTLICH ANGESEHENE UNTERLAGEN

Kategorie°	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
A	WO 96 18915 A (AMOCO CORP) 20. Juni 1996 (1996-06-20) in der Anmeldung erwähnt das ganze Dokument ---	1-10
A	US 5 706 194 A (NEFF DENNIS B ET AL) 6. Januar 1998 (1998-01-06) Spalte 3, Zeile 12 - Zeile 48 ---	1,8,9
A	WO 97 13166 A (AMOCO CORP) 10. April 1997 (1997-04-10) in der Anmeldung erwähnt Seite 4, Zeile 10 -Seite 5, Zeile 5 ---	1,4
A	WO 97 39367 A (AMOCO CORP) 23. Oktober 1997 (1997-10-23) in der Anmeldung erwähnt -----	

☐ Weitere Veröffentlichungen sind der Fortsetzung von Feld C zu entnehmen

☒ Siehe Anhang Patentfamilie

° Besondere Kategorien von angegebenen Veröffentlichungen :
"A" Veröffentlichung, die den allgemeinen Stand der Technik definiert, aber nicht als besonders bedeutsam anzusehen ist
"E" älteres Dokument, das jedoch erst am oder nach dem internationalen Anmeldedatum veröffentlicht worden ist
"L" Veröffentlichung, die geeignet ist, einen Prioritätsanspruch zweifelhaft erscheinen zu lassen, oder durch die das Veröffentlichungsdatum einer anderen im Recherchenbericht genannten Veröffentlichung belegt werden soll oder die aus einem anderen besonderen Grund angegeben ist (wie ausgeführt)
"O" Veröffentlichung, die sich auf eine mündliche Offenbarung, eine Benutzung, eine Ausstellung oder andere Maßnahmen bezieht
"P" Veröffentlichung, die vor dem internationalen Anmeldedatum, aber nach dem beanspruchten Prioritätsdatum veröffentlicht worden ist

"T" Spätere Veröffentlichung, die nach dem internationalen Anmeldedatum oder dem Prioritätsdatum veröffentlicht worden ist und mit der Anmeldung nicht kollidiert, sondern nur zum Verständnis des der Erfindung zugrundeliegenden Prinzips oder der ihr zugrundeliegenden Theorie angegeben ist
"X" Veröffentlichung von besonderer Bedeutung; die beanspruchte Erfindung kann allein aufgrund dieser Veröffentlichung nicht als neu oder auf erfinderischer Tätigkeit beruhend betrachtet werden
"Y" Veröffentlichung von besonderer Bedeutung; die beanspruchte Erfindung kann nicht als auf erfinderischer Tätigkeit beruhend betrachtet werden, wenn die Veröffentlichung mit einer oder mehreren anderen Veröffentlichungen dieser Kategorie in Verbindung gebracht wird und diese Verbindung für einen Fachmann naheliegend ist
"&" Veröffentlichung, die Mitglied derselben Patentfamilie ist

Datum des Abschlusses der internationalen Recherche	Absendedatum des internationalen Recherchenberichts
28. November 2000	06/12/2000
Name und Postanschrift der Internationalen Recherchenbehörde	**Bevollmächtigter Bediensteter**
Europäisches Patentamt, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Swartjes, H

1

INTERNATIONAL SEARCH REPORT

Inform patent family members

Intern[illegible]al Application No
PC[illegible] 00/02000

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 9618915	A	20-06-1996	US	5563949	A	08-10-1996
			AU	696742	B	17-09-1998
			AU	4133396	A	03-07-1996
			CA	2179901	A,C	20-06-1996
			CN	1138902	A	25-12-1996
			EG	20609	A	30-09-1999
			EP	0736185	A	09-10-1996
			NO	962731	A	11-10-1996
			US	5930730	A	27-07-1999
			US	5838564	A	17-11-1998
US 5706194	A	06-01-1998	AU	673795	A	21-11-1996
			CA	2177771	A	02-12-1996
			EP	0745870	A	04-12-1996
			NO	962267	A	02-12-1996
WO 9713166	A	10-04-1997	US	5930730	A	27-07-1999
			AU	709621	B	02-09-1999
			AU	7382996	A	28-04-1997
			CA	2204168	A	10-04-1997
			CN	1166207	A	26-11-1997
			EP	0796442	A	24-09-1997
			NO	971801	A	05-06-1997
WO 9739367	A	23-10-1997	AU	710968	B	30-09-1999
			AU	1824797	A	07-11-1997
			CA	2220274	A	23-10-1997
			EP	0832442	A	01-04-1998
			NO	975784	A	12-02-1998
			US	5892732	A	06-04-1999